Different Re-excitation of Laser Induced Plasma for Enhancement and Prolongation of Spectral Emission – towards Precise Depth Profile Analysis

P. Veis[1,*], S. Soni[1], M. Veis[1], S. Atikukke[2], S.J. Shetty[1], K.E. Ramachandran[1], P.G.Bhat[1]

[1]*Dept. of Exp. Phys., FMPI, Comenius Univ., Mlynska dol. F2, 842 48 Bratislava, Slovakia*
[2]*DAPEM, FMPI, Comenius Univ., Mlynska dol. F2, 842 48 Bratislava, Slovakia*

In nuclear fusion, the first wall (FW) of fusion reactors and PFC are exposed to the heat flow, strong fluxes of energetic neutral particles, neutrons and plasma radiation. Plasma interactions with FW lead to sputtering of the material from the FW and consequent migration and re-deposition of sputtered particles at different places of the vessel. Fuel retention (D/T) in the FW poses safety concerns. Laser-induced breakdown spectroscopy (LIBS) can be used "in situ", "remotely" and is suitable for depth profile analysis of all elements (also low Z). Using ps laser, LIBS is suitable for retained gases (D/T, He, Ne,…) analysis [1-2]. FWs of fusion devices (e.g. JET, WEST, ITER) are from tungsten (W) as W has highest melting temperature and good resistance for high heat flow. But W and other suitable high Z materials have very high number of spectral lines (several thousand of spectral lines in the range 200-1000 nm). Lasers with shorter pulses are better for gas detection in material (shorter ablation time, low heat-affected zones and less ablated material) resulting also in better depth resolution. However, ps Laser Induced Plasma (LIP) exhibits often lower plasma temperature T_e, insufficient for efficient excitation H isotopes, He and Ne atomic states. This study explores different LIP re-excitation using MW [3-5] or Resonant (R) LIBS [6] to address these problems.

In MW LIBS experiment, metallic samples (Al, brass,…) were ablated by ns Nd:YAG laser (1064 nm, 7 ns, 5 mJ) under air and Ar atmospheres (100-1000 mbar). The monopole MW antenna (set at 45° closed to the sample) so that the pulsed MW discharge would ignite just after LIP ignition [7]. The OES were collected through the echelle spectrometer (ME5000, Andor, 200-1000nm) coupled with an iCCD camera (iStar DH734, Andor, gate width 5 µs). Compared with LIBS, MW LIBS prolongs significantly the plasma lifetime. Emission lines were narrower, detected even at 250 µs delay and the T_e, stays constant. The T_e was calculated by Boltzmann plots of different elements and Ar I lines, which T_e values of 0.55-0.91 eV, depending on the experimental conditions. Better homogeneity and longer plasma lifetime in MW LIBS are factors that raise the potential for calibration-free LIBS quantification.

RLIBS enhances depth resolution by tuning the nanosecond OPO laser (EKSPLA NT342C to match the resonance absorption of elements ablated from the sample. This reduces the ablation rate by since only a part of laser energy is used for ablation. As a result, RLIBS provides more precise depth profiling than conventional LIBS (e.g. for WTa sample in [7]).

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*Presenting author: pavel.veis@fmph.uniba.sk